Appendix E

Performance Tests for Linear Tomographic Units

A. Performance Tests for Tomographic Equipment

1. *Tomographic Cut Level Indicator*

a. Purpose: To determine the accuracy of the tomographic cut level indicator. Inaccuracy or nonreproducible results may produce a tomographic image missing information of diagnostic interest.

b. Regulations: The agreement of the indicated and the expected section levels should be within +/- 5mm for add-on equipment, +/- 1mm for dedicated tomographic units (see manufacturer specifications).

c. Equipment:

(1) 45 degree tomographic wedge with radiopaque centimeter scale or equivalently,

(2) Tomographic Test Tool

(3) Two 5mm thick Plexiglas attenuator blocks.

d. Procedure:

(1) Prepare the equipment to be tested for operation in the tomographic imaging mode. Select the most commonly used tomographic motion, exposure angle and sweep as clinically employed on the equipment.

(2) Load a cassette (11x14 inch or larger) in the cassette tray so the long axis is parallel with the long dimension of the x-ray table.

(3) Position the test wedge on the tabletop, linear systems, position the device so the number scale is perpendicular to the direction of motion. Position the Plexiglas attenuators on each side of the wedge. Set the field size to the cassette dimensions.

(4) If the RMI phantom is used, it should be centered over the film cassette with the step numbers perpendicular to the direction of motion. The RMI tool comes with 4, 2, and 1 cm spacers, allowing one to check any tomographic level from 1 to 80 mm.

(5) Using the means available with the equipment, set the cut level indicator to provide a cut level of 15 cm anterior to the tabletop.

(6) Set technique of 60 kVp (or less) and 50 mAs.

(7) Make a tomographic exposure and process the exposed film. Evaluate the film for the necessary density to interpret the numerical readings of the centimeter scale.

(8) Record all parameters used (exposure technique, tomo unit settings).

(9) Repeat the test for cut levels of 3, 5, and 7 cm and for other exposure angles, sweep speeds and motions clinically used.

e. Interpretation Of Test Results:

(1) View the processed film on a radiographic illuminator. Determine on the image of the 45^{o} tomographic test wedge the wire in the test image that is in sharpest focus. From the scale determine the centimeter height to which this corresponds. Record this value. Compare the measured value of the cut level to the indicated value and record the difference.

(2) Determine on the image of the RMI test tool the numeral that is in sharpest focus. Normally, this number will be bordered by tow numbers which are partially blurred while the rest of the numerals will show ever increasing blurring. The number in sharpest focus corresponds to the cut height (when the spacer height, 10, 20, or 40 mm is factored in.) Record this value.

2. ***Tomographic Exposure Angle***:

a. Purpose: Exposure angle is inversely related to cut thickness. Tomographic sections that are too thick or too thin to often reveal little of diagnostic interest and may result in inaccurate or non-reproducible images. This test will determine the exposure angle during a tomographic exposure and compare it with the indicated exposure angle.

b. Regulation: The agreement of the indicated and the measured exposure angles should be within +/- 5 degrees for units operating at angles greater than 30 degrees; for smaller tomographic angles, the agreement between indicated and measured should be closer. For units employing symmetric motion at wide angles, the symmetry of exposure angle should be within 5 degrees with respect to the centerline

c. Equipment:

(1) 45 degree tomographic wedge with radiopaque centimeter scale; may be difficult to obtain. Biomedical Engineering technicians (BMETs)should have one you can ask to borrow.

(2) Two 5mm thick Plexiglas attenuator blocks.

d. Procedure:

(1) Select the most commonly used tomographic motion, exposure angle and sweep speed used for clinical tomographic imaging.

(2) With the x-ray tube perpendicular to the table or using the equipment's centering light, position the tomographic test wedge in the center of the field so the 12.5 cm scale marker is coincident with the central ray. For linear systems, orient the wedge so the scale is perpendicular to the direction of the tube motion. Place the Plexiglas attenuators on each side of the wedge.

(3) Place at least a 11x24 inch cassette in the cassette tray oriented with the long axis along the long axis of the table.

(4) Select technique of 60 kVp and approximately 50 mAs.

(5) Select a cut level of 12.5 cm and make the tomographic exposure.

(6) Process the film and record all techniques and tomographic parameters.

(7) Repeat the procedure for other exposure angles and tomographic motions used clinically.

e. Interpretation Of Results:

(1) In the tomogram, the image of the long diagonal wire will appear as two blurred triangles, see Figure E-1. The apex of each triangle will appear in sharp focus at the level of cut. On the image, reconstruct with a ruler and film marking pencil the outline of these triangles. Select one of the triangles and using the reference scale as a guide, draw a baseline to the triangle. From the scale markings, determine the distance from the apex of the triangle drawn to the baseline. Using a centimeter ruler, measure the width of the reconstructed triangle at the drawn baseline. Let the distance from the triangle baseline to the apex be "b", and the baseline width be "c". The tomographic exposure angle "α," is then determined by:

$$\alpha = 2 \tan^{-1} (c/2b)$$

Calculate the quantity, (c/2b), and with the aid of Figure E-2, or using your calculator, determine the value of $\tan^{-1}$ that corresponds with that quantity. Tan^{-1} (c/2b) corresponds to one-half the tomographic exposure angle α when the value "c" is used in the calculation and to the tomographic exposure half angles $\alpha 1$ and $\alpha 2$ where c_1 and c_2 are used in the calculation respectively.

(2) The exposure angle should also be evaluated for symmetry about the midline of the exposure. This may be done by constructing a perpendicular line for the baseline of the reconstructed triangle through the apex of the triangle and calculating the exposure half angle as:

$$\alpha 1 = 2 \tan^{-1} (c1/2b) \text{ and } \alpha 2 = 2 \tan^{-1} (c2/2b)$$

3. ***Tomographic Cut Thickness***

a. Purpose: To visualize different anatomical features, tomographic sections of different thicknesses are used. The tomographic unit's ability to reproduce consistent cut thicknesses is essential in meeting this requirement.

b. Regulation: This characteristic varies with type of tomographic motion, exposure angle and uniformity. Tolerance limits should be determined when the machine is acceptance tested. These results may then be used for future comparison tests. Manufacturer specifications may also be used for comparison test evaluation.

c. Equipment:

(1) 45 degree tomographic wedge with radiopaque centimeter scale.

(2) Two 5mm thick Plexiglas attenuator blocks.

d. Procedure:

(1) Insert 11x14 inch cassette (minimum) into cassette tray.

(2) With the x-ray tube perpendicular to the tabletop or using the system's centering light, position the tomographic test tool so the 12.5 cm mark on the scale is coincident with the central ray. For linear systems, the test tool should be oriented so that the scale is parallel to the direction of the tube travel. Place the Plexiglas attenuators on each sides of the wedge

(3) Select the most commonly used tomographic motion, sweep speed and exposure angle used clinically. Select cut level of 12.5 cm.

(4) Select exposure technique of 60 kVp and 30 mAs.

(5) Make the exposure and process the film. Record all tomographic setup parameters.

(6) Repeat #5 for all commonly used tomographic motions, sweep speeds and exposure angles.

e. Interpretation Of Results:

(1) View each film on a radiographic illuminator. The image of the wires on the tomographic scale will be in varying degrees of focus. The wire in the sharpest focus is the level of the cut plane. To either side of this wire the focus will decrease.

(2) Determine the distance on both sides from the sharpest focus point over which the wire images remain in reasonable focus. The sum of each distance is the thickness of the cut plane.

4. *Flatness Of The Tomographic Plane*

a. Purpose: The intent of tomography is to better visualize a plane of the patient's anatomy. Mechanical instability in the tomographic unit may result in non-flat sectional images. This loss of flatness may be interpreted incorrectly as an unusual anatomical configuration in the patient. This test will determine the flatness of the tomographic cut plane.

b. Regulation: Add on tomographic devices to routine x-ray units and linear tomographic units should have a cut plane flatness of +/- 3mm. Dedicated tomography units should have a cut plane flatness of +/- 2mm

c. Equipment:

(1) 45 degree tomographic wedge with radiopaque centimeter scale.

(2) Two 5mm thick Plexiglas attenuator blocks.

d. Procedure:

(1) Place 14x17 inch cassette into tray.

(2) With the x-ray beam perpendicular to the tabletop, adjust the field size to the cassette dimensions. Using the light localizer, position the test wedge in the upper left quadrant of the light field so that the 12 cm point on the cm scale is in the approximate center of the quadrant. For linear systems, the wedge scale should be parallel to the direction of the tube travel. Place the Plexiglas attenuators on each side of the wedge

(3) Select the tomographic motion, sweep speed and exposure angle most commonly used. For

ease in test interpretations, the largest exposure angle available should be used.

(4) Set the cut level indicator to 12 cm.

(5) Set technique for 60 kVp and approximately 50 mAs.

(6) Make and exposure and process the film. Identify parameters used and quadrant on film and data sheet.

(7) Make three additional tomographic test films but move the wedge to the center of the remaining quadrants between exposures.

(8) Repeat test procedure for other tomographic motions, sweep speeds and exposure angles clinically used.

e. Interpretation Of Results:

(1) View the complete test films on a radiographic illuminator. For each test film, determine the scale marker that is in maximum focus (cut level). The point of the scale that is in the sharpest focus should be the same regardless of the quadrant in which the test device was imaged.

5. ***Uniformity Of Tomographic Exposure***

a. Purpose: A non-uniform exposure over the arc of motion of the tomographic unit yields an effective tomographic angle different from that indicated by the exposure angle indicator. Additionally, non-uniform exposure can increase the susceptibility of the tomographic unit to produce streaks and artifacts in the image.

b. Regulation: Closure of all motions should be complete, exhibiting no open gaps, no asymmetries. Overlap in general should not exceed 20 degrees. Single phase units may be displayed as a series of overlapping dots. If the density of the reproduced trajectory is measured with a densitometer, the maximum density variation should not be greater than 0.3 density units

c. Equipment:

(1) Lead aperture plate (6 x 6 inch plate, with 1/8 inch hole).

(2) Plexiglas attenuator block (6x6x3/4 inch).

d. Procedure:

(1) Place 8 x 10 inch cassette in tray and adjust field to 3x3 inch in the plane of the image receptor.

(2) With the x-ray tube perpendicular to the table or using the center positioning light on the unit, position the lead aperture plate on top of the 5 cm thick Plexiglas spacer and position on the tabletop so the hole in the plate is coincident with the central ray of the x-ray field.

(3) Select the most commonly used tomographic motion, exposure angle and sweep speed. Set indicated cut level to 12 cm.

(4) Set technique of 60 kVp, and approximately 100 mAs. The technique may have to be altered to attain an image that has a density in the range of 1.0 to 1.5 in the area of the aperture image.

(5) Make an exposure, return to vertical and make 1 additional exposure and process the film

(6) Repeat above for each clinically used tomographic motion, exposure angle and sweep speed.

e. Interpretation Of Results:

(1) The tomographic image of the hole in the aperture place is a radiographic reproduction of the trajectory of the x-ray tube during the tomographic exposure. When the test images are viewed, the density of the image over the reproduced trajectory should appear uniform. Variations of the uniformity of the image density are indicative of mechanical problems in the tomographic drive mechanism.

(2) The images should also be evaluated to determine stability of tube motion i.e. the pattern reproduced on a linear system should be uniform in density and describe as a straight line, not a wobbly one and should be of equal length each side of center.

6. ***Tomographic Resolution***

a. Purpose: Clarity of anatomical information is critically dependent upon the spatial resolution provided by the tomographic unit.

b. Regulation: Most tomographic units should be able to visualize 30 to 40 mesh wire.

c. Equipment:

(1) Tomographic resolution test object embedded in acrylic.

(2) Two 6x6x2 inch Plexiglas attenuator blocks.

e. Procedure:

(1) Select tomographic motion, sweep speed and exposure angle used most commonly for clinical imaging. Select a cut level of 10.5 cm.

(2) Position the two 5 cm (2 inch) thick spacer blocks, with the resolution test object on top of the two blocks, on the tabletop and center with respect to the tomographic field. For linear systems, orient the resolution test object so that the slope of the wire mesh patterns is perpendicular to the direction of the tube travel.

(3) Select technique of 60 kVp and approximately 20 mAs.

(4) Insert 8 x 10 inch cassette to the cassette tray. Collimate the field to the cassette dimensions.

(5) Expose and process the film.

(6) Repeat above for each clinically used tomographic motion, sweep speeds and exposure angles.

f. Interpretation Of Results:

(1) View each film on a radiographic illuminator. Determine the finest mesh which is just resolved. The mesh will be in best focus at the level of the cut plane. The mesh patterns are: 20, 30, 40 and 50 mesh holes per inch.

7. ***Representative Entrance Skin Exposures***

See chapter 15 and appendix I.